

JOURNAL OF THE
BOSTON SOCIETY
OF
CIVIL ENGINEERS



JUNE - 1932

VOLUME XIX

NUMBER 6

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Published Monthly, except July and August, by the Society
715 Tremont Temple, Boston, Massachusetts

Subscription Price, \$4.00 a Year (10 Copies)
50 Cents a Copy

Copyright, 1932, by the Boston Society of Civil Engineers.
Entered as second-class matter, January 15, 1914, at the Post Office
at Boston, Mass., under Act of August 24, 1912.

Acceptance for mailing at special rate of postage provided for in
Section 1103, Act of October 3, 1917, authorized on July 16, 1918.

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BOSTON
WRIGHT & POTTER PRINTING COMPANY
32 DERNE STREET

JOURNAL OF THE BOSTON SOCIETY OF CIVIL ENGINEERS

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HYDRAULICS OF SEWER TRANSITIONS

THOMAS R. CAMP,* MEMBER

(Presented at a meeting of the Sanitary Section of the Boston Society of Civil Engineers, March 2, 1932)

THIS paper was originally contemplated to cover the subject of the hydraulic design of treatment plants. In its development, however, it soon became apparent that it would have to be more limited in its scope. For example, no attempt has been made to discuss flow conditions which occur in the influent and effluent channels of tanks and in underdrainage systems of rapid filters. In each of these units the discharge changes along the conduit. Some studies are now being made at the Massachusetts Institute of Technology on the flow in effluent channels, and I hope to give a paper on that subject at a later date. This paper has therefore been limited to steady flow conditions, and while the principles brought out apply to water treatment plants, sewage treatment plants or sewers they apply only to open channel flow.

The hydraulics of sewer transitions is concerned essentially with control sections, the conversion of pressure head to velocity head, and the conversion of velocity head to pressure head.

In order to approach the subject we must review the study of the energy at a section, which may be expressed by means of Bernoulli's theorem. From this, it will be possible to develop the meaning of the term "control section."

* Associate Professor of Sanitary Engineering, Massachusetts Institute of Technology.

ENERGY AT A SECTION

With the bottom of the channel (Fig. 1) as a datum, we may write, by means of Bernoulli's theorem, the following expression for the total energy per pound of water:

$$H = z + h + \frac{v^2}{2g} \quad (1)$$

This is true at any section.

It is important to note here that the energy line in these figures will be at the same location wherever the datum be taken; that is, z may be any value, positive or negative, without affecting the posi-

$$H = z + h + \frac{v^2}{2g} \quad (1)$$

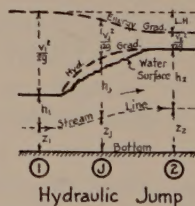
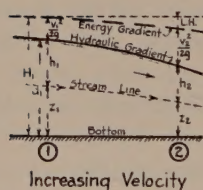
$$H = d + \frac{v^2}{2g} \quad (1a)$$

$$H = d + \frac{Q^2}{2gA^2} \quad (1b)$$

For rectangular channels, if q is the discharge per foot width,

$$H = d + \frac{q^2}{2gd^2} \quad (1c)$$

$$\text{If } x = \frac{d}{H}, \quad x^3 - x^2 + \frac{q^2}{2gH^3} = 0 \quad (2)$$



ANALYSIS OF ENERGY AT A SECTION

FIG. 1

tion of the energy gradient. Moreover, we may raise or lower the bottom, change the shape of the conduit, and the energy gradient is still in the same position, provided we do not change the position of the water surface or the magnitude of the velocity. Also, we may change the velocity, and if we change the water surface an amount sufficient to compensate for the change in velocity head the energy gradient remains in its original location. The only factor which affects the difference in elevation of the energy gradient between any two sections is the friction loss. Therefore the energy gradient is itself a more convenient datum or base line to work from than is the invert. This will become more apparent in the applications given near the end of the paper.

If the water surface is not curved too much, for practical purposes —

$$z+h=d$$

and —

$$H=d+\frac{v^2}{2g} \quad (1a)$$

It will be shown later that with non-parallel stream lines the pressure head, h , above any stream line is not equal to the depth of water above.

Since the quantity of water flowing in each section is the same, the above formulas for the energy per pound of water may be applied to the total quantity flowing, provided v is the same for each pound.

This is not true, of course; but if the mean velocity $\frac{Q}{A}$ be used, it may be shown that for most cases the neglect to account for the variation in the velocity over the cross section will not affect the value of the velocity head an appreciable amount. For practical purposes, then, the mean velocity in the cross section may be used to compute the velocity head without serious error. Substituting this value in (1a) —

$$H=d+\frac{Q^2}{2gA^2} \quad (1b)$$

This is a general formula for any open channel in which the water is flowing substantially parallel to the bottom.

The cross section area A is some function of the depth d for any shape of cross section. If its value in terms of d be substituted for A in (1b), a cubical equation in terms of d results. This equation has three roots, two of which are positive and one of which is negative. The negative value of d may be disregarded. The two positive values, however, are real and represent the two alternate stages at which the quantity Q may flow with the given energy H .

For rectangular channels, (1b) may be written —

$$H=d+\frac{q^2}{2gd^2} \quad (1c)$$

where q is the discharge per foot of channel width. For facility in the solution of this equation, Groat (see discussion of Kennison's paper

"The Hydraulic Jump in Open Channel Flow," Transactions, A. S. C. E., 1916, page 354) suggests that it be written —

$$x^3 - x^2 + \frac{q^2}{2gH^3} = 0 \quad (2)$$

where x is the ratio $\frac{d}{H}$.

Equation (2) is shown graphically in Fig. 2 for the two positive values of d . The conditions of flow in any rectangular section may be examined very readily by means of this curve.

A similar development has been made by the writer for conduits with a circular cross section flowing partly full (see Engineering News-Record, Vol. 104, page 106). The treatment for circular pipes is largely graphical because of the difficulties of mathematical analysis. In this case the area of the cross section is a function of the diameter of the pipe, D , as well as the depth, and therefore another variable enters into the equations. A single curve as for rectangular channels will not suffice.

Fig. 3 shows a diagram with a number of curves such as are shown in Fig. 2, each of which is for a different ratio of $\frac{H}{D}$. This diagram may be used to study the conditions of flow in any circular conduit. It will be noted that the abscissas in this case are in terms of $\frac{Q^2}{2gHD^4}$, where Q is the total discharge and D is the diameter.

King (Handbook of Hydraulics) gives tables for computing the alternate stages of flow for trapezoidal and V-shaped cross sections. The two stages of flow for a given energy head are possible for any shape of cross section, but the mathematical treatment is difficult for irregular shapes.

We are now ready to take up the consideration of control sections.

CONTROL SECTIONS

It will be noted in Fig. 2 for rectangular sections that there is a certain maximum value of $\frac{q^2}{2gH^3}$, at which value the two alternate stages become one. For any given discharge, q , the maximum value of $\frac{q^2}{2gH^3}$ occurs with a minimum total energy, H ; or, conversely, with any given value of H it occurs with a maximum discharge, q . The re-

lations of the variables at this flow condition may be obtained by differentiating the value of q or H in equation (1c) with respect to the depth d and setting the derivative equal to zero. This stage of flow is known as the critical stage, and the depth and velocity are called the critical. A section at which flow at the critical stage occurs is called a "control section."

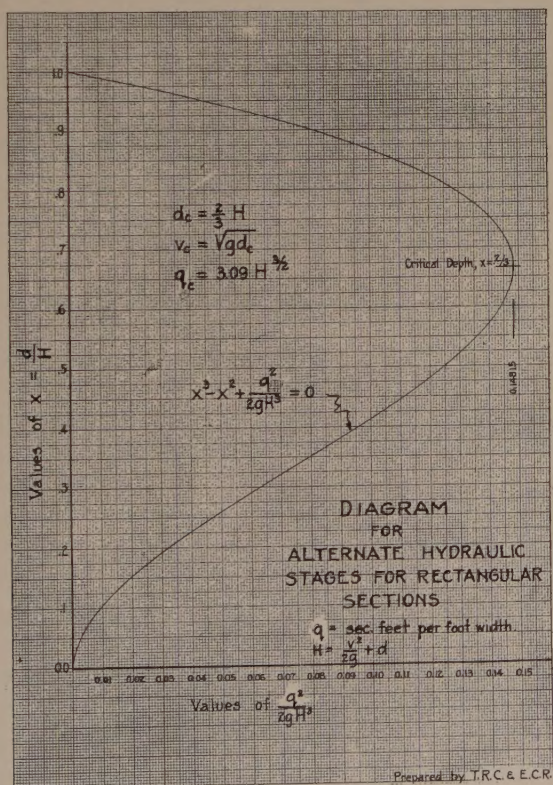


FIG. 2

By solving the derivatives of either q or H the following relations will be found for rectangular control sections:

$$d_c = \frac{2}{3} H \quad (3)$$

$$v_c = \sqrt{gd_c} \quad (4)$$

$$q_c = 3.09 H^{3/2} \quad (5)$$

The subscript c indicates flow at the critical stage. The maximum value of $\frac{q^2}{2gH^3}$ will be found from these relations to be 4/27ths, or 0.14815.

Referring to the curves for circular conduits (Fig. 3), it is found that similar maximum values exist for $\frac{Q^2}{2gHD^4}$ for each $\frac{H}{D}$ curve. It will be noted, however, that for the circular sections the ratio x of critical depth to total energy is not a constant as it is in rectangular channels. It varies from a maximum value of about 0.76 for very low values of $\frac{H}{D}$ to very much smaller values as the pipe flows more nearly full and as the velocities become very high. The critical depth line is asymptotic to the $\frac{d}{D} = 1.0$ line, indicating that there is no critical stage for full pipes.

A scale of values of $\frac{Q^2}{D^5}$ is given at the top of the chart to facilitate the finding of the critical depth without the necessity of computing H .

Control sections of this type may occur with any shape of cross section. King gives the development of relations for trapezoidal and V-shaped channels. Shapes which are more irregular are difficult to handle mathematically.

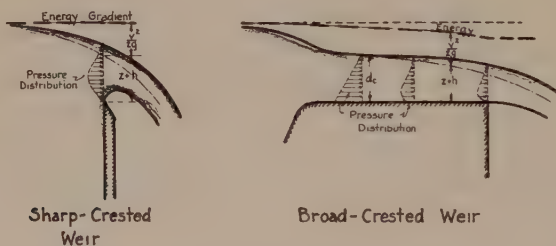
It is important to recognize here that the control sections above defined and treated are premised upon a straight line variation of hydraulic pressure in the cross section. The pressure head at any depth is equal to the depth of water above. Such a pressure distribution occurs only when the stream lines are straight and parallel, that is, when the surface profile is parallel to the bottom of the channel. This type of control section is therefore a very special one which seldom exists in practice.

The "critical depth" may readily exist in practice if the slope of the conduit is just that which will cause uniform flow at this depth. The conduit itself can hardly be classed as a control section, however. In order to differentiate this special type from those control sections which are more commonly met with in practice, it will be convenient to call it a "hydrostatic control section," inasmuch as its characteristics are developed from the assumption of a hydrostatic pressure distribution.

The commonest type of control section met with in treatment plants is that which occurs at a weir, usually a sharp-crested weir at the effluent end of a tank. Broad-crested weirs are also sometimes found in treatment plants. The shape of the weir crest greatly affects

the pressure distribution in the section or sections over the crest, but in no case is this distribution at the weir a hydrostatic one. The pressure distribution at both these types of weirs is shown roughly on Fig. 4.

With sharp-crested weirs, the pressure is atmospheric both above and below the nappe, assuming full ventilation below the nappe. The pressure distribution within the nappe is determined by the rate of contraction or convergence of the stream lines. With broad-crested weirs the rate of contraction may be made less, and if the weir is a comparatively flat one and broad enough a control section closely approximating a "hydrostatic" one may be found at some point back from the discharge end. At the discharge end, however, if free fall is permitted, the pressure is again atmospheric under the nappe.



COMMON TYPES OF CONTROL SECTIONS

FIG. 4

An interesting series of experiments on broad-crested weirs has been conducted at Washington State College by Prof. James G. Woodburn (see Proceedings, A. S. C. E., September, 1930, and subsequent discussions). Similar studies are also being made by Hunter Rouse in the River Hydraulic Laboratory at the Massachusetts Institute of Technology.

A common type of control section, chiefly met with in outfall sewers, is that which exists near the end of a freely discharging pipe or flume of gentle slope. In the case of a rectangular flume this type resembles a broad-crested weir. For the control section to exist, however, it is essential that the slope of the conduit be such as to maintain flow upstream from the control section at the upper stage. The pressure at the end of the pipe is atmospheric both above and below the free falling water. At some point back from the end, the flow will pass through a stage closely approximating a hydrostatic control section.

According to Rouse, this control section is farthest from the end of conduits, with very flat slopes and smooth surfaces; that is, when the friction loss at the end is least. From his experiments with broad-crested weirs, Rouse estimates that the critical depth is not farther away from the end in any practical case than about five times the value of the critical depth. The depth at the extreme end of the conduit is always less than the critical, and the energy is less than that at the control section by the amount lost in friction below the control section. For practical purposes, with long outfall sewers it is sufficiently accurate to assume that the control section exists at the end of the pipe.

Freely discharging sluice gates and orifices may also be called control sections.

The most important characteristic to the designer of all the types of control sections so far described is that the depth of flow and the energy at the control section are entirely independent of conditions downstream. The depth of flow and energy are dependent wholly upon the physical features of the control section at any given discharge. The hydraulic design must, therefore, start at control sections and proceed thence upstream.

In treatment plants or in sewers, that which is a control section under some conditions of flow may be partly or completely submerged at times of high flow. Under such conditions the section ceases to be a point of control, and hydraulic computations must start from another point of control downstream. The characteristics of the section will usually be much changed under submergence and the energy at the section increased.

Another important characteristic of control sections to the designer is that with all of them the energy is a minimum for any given discharge, and the discharge therefor bears a definite relation to the total energy.

It is sometimes difficult in design to determine the location of control sections. This may be facilitated if it be remembered that a control section can exist only at a point where there is a passage to the critical stage from the upper stage. Usually the passage is through the critical stage to the lower stage, but with a raised bottom the passage from the critical stage back to the upper stage may sometimes occur. The critical depth does not occur following flow at the lower stage except in the same very special case of a raised bottom in transition from the lower to the upper stage.

In the case of an hydraulic jump (see Fig. 1) the flow does not pass through the critical stage because the energy is greater than the

minimum both before and after the jump and cannot be less within it. The additional energy within the jump which is required to satisfy this evident fact will be found in the additional pressure energy which is due to the diverging flow. This additional pressure energy is shown on the figure above the water surface up to the dash line, which represents the hydraulic gradient. This apparent anomaly will be explained in detail at the end of the paper.

The end of a conduit carrying water at the lower alternate stage is not a control section because the critical velocity is less than the velocity at the lower stage, and the velocity does not decrease near the end of the conduit. The energy conditions at the end of such a conduit are determined from the conditions upstream. Fig. 5 shows roughly

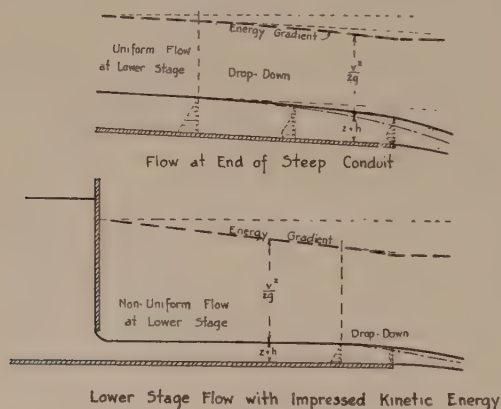


FIG. 5

the flow and pressure conditions at the end of a conduit where flow is at the lower stage.

If the flow is at the lower stage wholly because of the slope of the conduit, the depth and conditions of uniform flow may be determined from friction formulæ and the energy gradient is parallel to the invert until the drop-down curve is reached near the end of the pipe. From this point to the end of the pipe the pressure does not have a hydrostatic distribution and the hydrostatic energy becomes less than the depth. The velocity increases, but not as fast as the pressure energy decreases. Hence there is an increase in the slope of the energy gradient.

If considerable kinetic energy is imparted to the stream by a head of water above some gate upstream, the velocity and total energy just

below the gate are functions wholly of this head and bear no relation to the dimensions and slope of the conduit. The slope of the energy gradient and the resulting energy at the end of the conduit are, of course, dependent upon the friction loss between the gate and the end of the conduit.

We may now take up the discussion of transitions.

TRANSITIONS

A transition is any portion of a conduit in which non-uniform flow takes place. The velocities are usually low in transitions for sanitary sewers and treatment plants, and the flow through such transitions, therefore, occurs at the upper stage. Flow at the lower stage is not uncommon in storm drain transitions. Generally speaking, there is in all transitions a conversion of pressure head to velocity head or of velocity head to pressure head. The transition may be from the higher stage to the higher, from the higher to the lower, from the lower to the higher (with or without a jump), or from the lower to the lower. In every case a change of velocity occurs.

The problem in the design of transitions consists of solving the conditions of flow at any section from known conditions at another section. In most cases the design must be carried upstream, starting at some control section or from some known water surface elevation.

If no loss of energy is assumed, the energy line will be horizontal. With losses considered, the energy line will be sloping upstream (see Fig. 1). With gradual transitions, such as drop-down and backwater curves in long conduits, the slope of the energy line may be determined by the use of the Chezy formula —

$$v = C \sqrt{RS}$$

or other similar empirical formulæ for friction loss. With such long transitions, the usual method of designing is to assume some given depth upstream from the point of known conditions and compute an energy slope corresponding to the average of the velocities at the two sections. The distance to the point of assumed depth may then be computed approximately. This method is well illustrated by Metcalf & Eddy in their works on sewer design, and it need not be discussed further here.

Short, abrupt transitions, such as occur in treatment plants and

in changes from one sewer size to another, or from one slope to another, are best designed by first estimating the total lost energy through the transition and then distributing this loss to best advantage along the length of the transition. Unfortunately, very little is known about the amount of energy lost in a short transition. We do know, however, that for low velocities the losses are small, and great errors in their assumption will have small effect upon the resulting design. For the high velocities which occur in some storm drain transitions, errors in the assumption of losses will be of far greater importance.

Probably the best information which has been published in this country as to the value of losses in short transitions is contained in the paper by Julian Hinds, "Hydraulic Design of Flume and Siphon Transitions" (Transactions, A. S. C. E., Vol. 92, 1928, page 1423). Hinds states that for well designed transitions in the upper stage the loss is likely to be less than 5 per cent of the change in velocity heads for increasing velocity transitions, and that 10 per cent of the change in velocity head may be safely assumed in design. For decreasing velocity of expanding transitions, the loss may be expected to be less than 10 per cent of the change in velocity head, and 20 per cent of this change may safely be assumed for design. Methods for computing the shapes of transitions are clearly described by Hinds.

It is quite important to realize in designing transitions that the procedure must be from the energy gradient downward. At any starting section, at which the hydraulic conditions are known, the location of the energy gradient is determined. From this, the location of the gradient at any point upstream may be determined by adding the lost energy. Now, if the elevation of the bottom and the width of the channel at this point are fixed, the depth must be solved. If the velocity is fixed, the surface of the water is thereby fixed and the depth and width may be anything which together will produce the given velocity.

The usefulness of the foregoing diagrams in the design of transitions may best be brought out by some practical applications.

PRACTICAL APPLICATIONS

In the following examples the assumption of hydrostatic pressure distribution is made for all sections.

In Example No. 1 (Fig. 6) we have given a flat-bottom, rectangular channel with flow converging from a 10-foot width to a 5-foot width.

The problem is to find the critical depth and minimum energy at the throat for a discharge of 200 c. f. s. The discharge per foot of width is —

$$q = \frac{200}{5} = 40$$

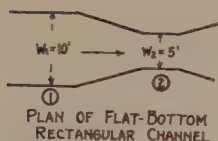
$$\frac{q^2}{2gH^3} = 0.14815 \quad (\text{See Fig. 2})$$

whence —

$$H^3 = \frac{1600}{64.4 \times 0.14815} = 167.7$$

$$H = 5.52$$

$$d_c = 2/3 \times 5.52 = 3.67 \text{ ft.}$$



Example No. 1

Find d_c and H_{min} at 2 for $Q = 200$ c.f.s.

$$q = \frac{200}{5} = 40$$

$$\frac{q^2}{2gH^3} = 0.14815$$

$$\text{Whence } H^3 = \frac{1600}{64.4 \times 0.14815} = 167.7$$

$$H = 5.52$$

$$d_c = \frac{2}{3} \times 5.52 = 3.67'$$

Example No. 2

$Q = 200$ c.f.s. $d_1 = 6.0$

Find d_2 , assuming no loss

At 1,

$$Wd_1 = A_1 = 60$$

$$v_1 = \frac{200}{60} = 3.33$$

$$\frac{v_1^2}{2g} = 0.172'$$

$$\frac{d_1}{d_2} = \frac{6.000}{6.000}$$

$$H_1 = 6.172' = H_2$$

At 2,

$$q = 40$$

$$\frac{q^2}{2gH^3} = \frac{1600}{64.4 \times 6.172^3} = 0.1056$$

From chart, $x_u = 0.855$

$$d_2 = 0.855 \times 6.172 = 5.28$$

FIG. 6

In Example No. 2 (Fig. 6) with the same transition and the same discharge, a depth of 6 feet is assumed at the upstream section, and the problem is to determine the depth at the throat, assuming no loss.

At section 1 —

$$W_1 d_1 = A_1 = 60$$

$$v_1 = \frac{200}{60} = 3.33$$

$$\frac{v_1^2}{2g} = 0.172 \text{ ft.}$$

$$\frac{d_1 = 6.000}{H_1 = 6.172 \text{ ft.}} = H^2$$

At section 2 —

$$q = 40$$

$$\frac{q^2}{2gH^3} = \frac{1600}{64.4 \times 6.172^3} = 0.1056$$

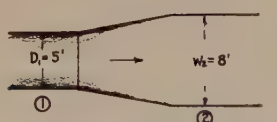
From the chart (Fig. 2) —

$$x_u = 0.855$$

Hence —

$$d_2 = 0.855 \times 6.172 = 5.28$$

The following examples (Fig. 7) have to do with an expanding transition from a 5-foot pipe to a rectangular flume 8 feet wide:



PLAN OF FLAT INVERT TRANSITION
PIPE TO RECTANGULAR CHANNEL
 $Q = 200$ c. f. s.

Example No. 3

Find critical depth in pipe

$$\frac{Q^2}{D^5} = \frac{40,000}{3,125} = 12.80. \text{ From chart, } x = 0.65$$

$$\text{and } \frac{H}{D} = 1.25. \text{ Hence, } H = 1.25 \times 5 = 6.25'$$

$$\text{and } d_c = 0.65 \times 6.25 = 4.06'$$

Example No. 4

Find depth in pipe if $H = 7.5'$

$$\frac{H}{D} = 1.5 \quad \frac{Q^2}{2gHD^4} = \frac{40,000}{64.4 \times 7.5 \times 625} = 0.1325$$

$$\text{From chart, } x_1 = 0.38 \quad d_1 = 0.38 \times 7.5 = 2.85$$

$$x_u = 0.785 \quad d_u = 0.785 \times 7.5 = 5.89$$

For upper stage flow, the pipe is under a pressure at the top of 0.89'

Example No. 5

$$Q = 130, d_1 = 4.0', v_1 = 7.73, d_2 = 5.5', L.H = 0.2\Delta v h_1$$

Find relative invert elevations

$$\begin{array}{lll} v_1 = 0.93 & v_2 = \frac{130}{8 \times 5.5} = 2.96 & v h_1 = 0.14 \\ d_1 = 4.00 & & d_2 = 5.50 \\ H_1 = 4.93 & & H_2 = 5.64 \end{array}$$

$$L.H = 0.2(0.93 - 0.14) = 0.16'$$

$$\text{Drop Rect. Chan. } 5.64 + 0.16 - 4.93 = 0.87'$$

$$\text{Water Surface rises } 0.93 - 0.16 - 0.14 = 0.53'$$

Example No. 6.

Find d_1 in above case with flat invert

$$H_1 = 5.64 + 0.16 = 5.80, \quad \frac{H_1}{D} = 1.16$$

$$\frac{Q^2}{2gHD^4} = \frac{16,900}{64.4 \times 5.80 \times 625} = 0.072$$

$$\text{From chart, } x_u = 0.883 \quad d_1 = 0.883 \times 5.8 = 5.12$$

Pipe flows under 0.12' pressure at top.

FIG. 7

In Example No. 3 the problem is to find the critical depth in the pipe for a discharge of 200 c. f. s.

$$\frac{Q^2}{D^5} = \frac{40,000}{3,125} = 12.80$$

From the chart (Fig. 3) —

$$x = 0.65$$

and —

$$\frac{H}{D} = 1.25$$

Hence —

$$H = 1.25 \times 5 = 6.25 \text{ ft.}$$

and —

$$d_e = 0.65 \times 6.25 = 4.06 \text{ ft.}$$

In Example No. 4 the problem is to find the depth of flow in the pipe for the same discharge if the total energy is 7.5 feet.

$$\frac{H}{D} = 1.5$$

$$\frac{Q}{2gHD^4} = \frac{40,000}{64.4 \times 7.5 \times 625} = 0.1325$$

From the chart (Fig. 3) —

$$x_l = 0.38$$

and —

$$d_l = 0.38 \times 7.5 = 2.85$$

$$x_u = 0.785$$

and —

$$d_u = 0.785 \times 7.5 = 5.89$$

It will be noted that 5.89 is greater than the diameter of the pipe. Hence for the upper stage the pipe is under a pressure at the top of 0.89 foot.

In Example No. 5 there is given a discharge of 130 c. f. s., a depth at section 1 of 4 feet, with a corresponding velocity at this section of 7.73 feet per second, and a depth at section 2 of 5.5 feet. The problem is to find the relation between the elevations of the inverts if the lost head between the sections is 20 per cent of the change in velocity head.

At section 1 —

$$vh_1 = 0.93$$

$$d_1 = 4.00$$

$$H_1 = 4.93$$

At section 2 —

$$v_2 = \frac{130}{8 \times 5.5} = 2.96$$

$$vh_2 = 0.14$$

$$d_2 = 5.50$$

$$H_2 = 5.64$$

The lost head —

$$L.H. = 0.2(0.93 - 0.14) = 0.16 \text{ ft.}$$

Therefore, the invert of the rectangular channel must be dropped below the invert of the pipe a distance equal to —

$$5.64 + 0.16 - 4.93 = 0.87 \text{ ft.}$$

In Example No. 6, the problem is to find the depth in the pipe if the discharge and the depth in the rectangular channel are the same as in Example No. 5, and if no drop is made in the invert. In this case —

$$H_1 = 5.64 + 0.16 = 5.80$$

$$\frac{H_1}{D} = 1.16$$

$$\frac{Q^2}{2gHD^4} = \frac{16,900}{64.4 \times 5.80 \times 625} = 0.072$$

With this value from the chart (Fig. 3) —

$$x_u = 0.883$$

and —

$$d_1 = 0.883 \times 5.8 = 5.12$$

Hence, for this case the pipe flows full and under 0.12 foot of head at the top.

It will be in order now to examine the actual distribution of pressure at a section.

PRESSURE DISTRIBUTION

The statement has been made several times in this paper that with curved stream lines the pressure head is not equal to the depth of water over a stream line. The effect of this phenomenon appears in the shapes of some of the pressure distribution curves which have been shown roughly on the foregoing figures. The effect is also noted on some of the figures by a hydraulic gradient which does not coincide with the water surface. In experiments on Venturi flumes conducted at the Massachusetts Institute of Technology by Muir and Miller in 1930, and by Silva in 1931 (see master's thesis by A. Silva, "A Study of

With uniform flow, the pressure necessary to prevent free fall is

$$p_v = \text{Mass} \times \text{Acceleration} = \frac{w}{g} g = w$$

or the weight of the water.

In a drop down curve,

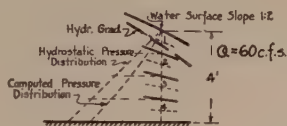
$$p_v = \frac{w}{g} (g - a)$$

where "a" is the acceleration of the water downward

If the water is falling freely, $a = g$ and the pressure is zero.

With a rising surface, such as in an hydraulic jump, the pressure is

$$p_v = \frac{w}{g} (g + a)$$



$$\text{Mean } v = \frac{60}{4} = 15' \text{ per sec.}$$

Hor. acceleration is computed to be $28.1'/\text{sec}^2$
Vert. accelerations for each stream line are:

$$a_1 = \frac{v^2}{r} \times 28.1 = 12.3$$

$$a_2 = \frac{v^2}{r} \times 28.1 = 8.79$$

$$a_3 = \frac{v^2}{r} \times 28.1 = 5.23$$

$$a_4 = \frac{v^2}{r} \times 28.1 = 1.76$$

Pressure upon each stream line to prevent free fall:

$$p_1 = 62.5 \times \frac{38.6 - 12.3}{32.16} = 38.6' \text{ sq. ft.}$$

$$p_2 = 62.5 \times \frac{38.6 - 8.79}{32.16} = 45.4$$

$$p_3 = 62.5 \times \frac{38.6 - 5.23}{32.16} = 52.3$$

$$p_4 = 62.5 \times \frac{38.6 - 1.76}{32.16} = 59.1$$

The head at the bottom of each stream line is:

$$h_1 = \frac{38.6}{22.5} = 0.62'$$

$$h_2 = \frac{29.4}{22.5} + 0.62 = 1.35'$$

$$h_3 = \frac{21.3}{22.5} + 0.35 = 2.19'$$

$$h_4 = \frac{9.1}{22.5} + 2.19 = 3.14'$$

FIG. 8

the Hydraulics of Open Channel Transitions"), the hydraulic gradient at the throat was found in some cases to be as much as 6 inches below the water surface. The location of the hydraulic gradient was determined with a piezometer.

The cause of this phenomenon is the vertical acceleration of the water. In uniform flow there is no vertical acceleration. Hence, the vertical force or pressure necessary to prevent free fall is —

$$p_v = \text{mass} \times \text{acceleration} = \frac{w}{g} g = w$$

or the weight of the water (see Fig. 8).

In a drop-down curve the vertical force acting upon a particle of water of weight w is —

$$p_v = \frac{w}{g} (g - a)$$

where a is the vertical acceleration of the particle. If the particle is falling freely, $a = g$ and the force or pressure is 0.

With a rising water surface, such as in an hydraulic jump, the acceleration is upward and the pressure on a particle is $p_v = \frac{w}{g} (g + a)$.

To determine the pressure upon the bottom or at any stream line, it is necessary to sum up the pressures exerted upon the particles in each stream line above the one under consideration.

Consider the simple case of the flat-bottom channel 4 feet deep discharging 60 c. f. s. per foot width and having a water surface slope of one in two.

As a rough approximation, assume four stream lines each a foot deep, and also assume that the horizontal velocity is the same for each stream line and is equal to —

$$v = \frac{60}{4} = 15 \text{ ft. per sec.}$$

Now, if we compute the horizontal acceleration, we will find that it is equal to approximately 28.1 feet per second and the vertical accelerations for each stream line are as follows:

$$a_1 = \frac{7}{16} \times 28.1 = 12.3$$

$$a_2 = \frac{5}{16} \times 28.1 = 8.79$$

$$a_3 = \frac{3}{16} \times 28.1 = 5.23$$

$$a_4 = \frac{1}{16} \times 28.1 = 1.76$$

In each of these stream lines the horizontal acceleration has been mul-

tiplied by the slope of the stream line. The pressure exerted upon each stream line to prevent free fall is —

$$p_1 = 62.5 \times \frac{32.16 - 12.3}{32.16} = 38.6 \text{ lbs./sq. ft.}$$

$$p_2 = 62.5 \times \frac{32.16 - 8.79}{32.16} = 45.4$$

$$p_3 = 62.5 \times \frac{32.16 - 5.23}{32.16} = 52.3$$

$$p_4 = 62.5 \times \frac{32.16 - 1.76}{32.16} = 59.1$$

The total head at the bottom of each stream line is —

$$h_1 = \frac{38.6}{62.5} = 0.62 \text{ ft.}$$

$$h_2 = 0.62 + \frac{45.4}{62.5} = 1.35 \text{ ft.}$$

$$h_3 = 1.35 + \frac{52.3}{62.5} = 2.19 \text{ ft.}$$

$$h_4 = 2.19 + \frac{59.1}{62.5} = 3.14 \text{ ft.}$$

The distribution of this head in comparison with the hydrostatic distribution is shown upon the diagram. You will note that it is less than the hydrostatic pressure.

The location of the hydraulic grade line (shown on the diagram as a heavy dash line) above the bottom may be computed by taking the average value of the static energy of all stream lines, or in this case —

$$z_a + h_a = \frac{Z(z+h)}{4} = 3.33 \text{ ft.}$$

The characteristics of this diagram, as has been stated, were determined on the assumption that the horizontal velocity is the same for each stream line. This assumption is never true in practice, and it is far from being the case at a weir (see Fig. 4).

At a weir crest the pressure is atmospheric at the bottom of the nappe. This means that for the lower stream lines there has been a conversion of static energy to kinetic, and all the energy for the lower stream line is in the form of velocity head. Hence, the water moves faster at the bottom of the nappe.

Fig. 9, which is drawn to scale, indicates the actual conditions of flow, as observed by Silva, through a small experimental Venturi flume at the Institute for a discharge of 1.46 c. f. s. It will be noted that the actual measured pressure-distribution curves at the throat are quite similar in shape to the one just computed approximately. At the entrance to the converging section the pressure has a hydrostatic distribution. In the middle of the diverging section the actual pressure

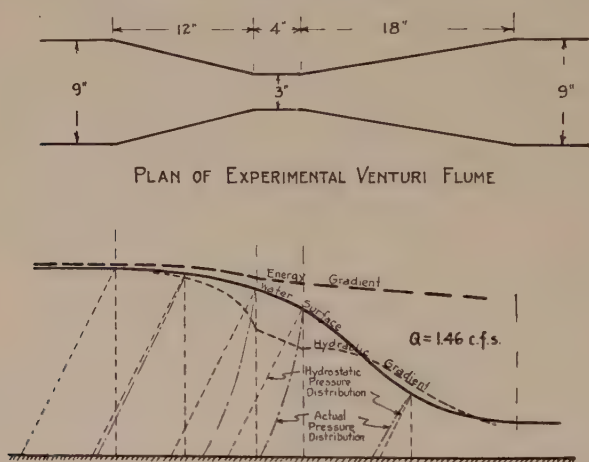


FIG. 9

distribution was found to be somewhat greater than the hydrostatic. This is due to a deceleration downward at this point which is equivalent to an acceleration upward. The hydraulic gradient has also been sketched in approximately on this diagram.

In closing, the writer wishes to emphasize the need for more experimental information upon the actual losses which occur through transitions, especially transitions where the velocities are high. More experimental information is also needed upon the shapes of hydraulic gradients. With sufficient information upon this subject, it is possible that we may be able to correlate rather closely the water surface slope with the pressure distribution, and hence to compute one from the other.

Discussion

KARL R. KENNISON:* The designer of hydraulic transitions should appreciate the precision of the formula applying to such phenomena as the hydraulic jump. The formula as originally developed by Unwin is merely a statement of the law that force is equal to the rate of change of momentum, and neglecting the inconsequential friction on the channel walls is inherently as precise as the law of the conservation of energy. In other words, in a straight rectangular channel, one does not have to apply any factor of safety or of ignorance in estimating the depth of water that will cause a hydraulic jump. The irregular surface waves which sometimes show below a control section appear to contradict the above statements, but actually do not do so. The reason for such waves is apparent when one examines the author's diagram in Fig. 2. This shows that there is a considerable range of vertical depths near the two-thirds depth which correspond practically to the same total energy gradient, — in other words, which correspond exactly to the same total energy gradient under very slight differences in pressure distribution throughout the depth from surface to bottom. These differences are intensified by the waves themselves, and easily produce an appearance of instability. As a matter of fact, the total or pressure gradient remains fixed, and under other conditions of depth than near the two-thirds point results in a fixed and easily computable water level.

Incidentally, it should be noted that the hydraulic jump formula expresses one of those relationships which have to be complicated to satisfy certain mathematical requirements, and for which a simpler formula not mathematically perfect but good enough for all purposes may be substituted. Such a substitute formula is $D = \frac{v\sqrt{d}}{4} - 0.45d$ in which v and d are the velocity and depth before the jump and D the depth after the jump (foot-second units), in a rectangular channel.

Frequent use has been made of the term "control section." My own definition of such a section is one whose characteristics are such that changes in the water level downstream therefrom have no effect on the rate of discharge. This is not only theoretically but practically true when the pressure distribution is hydrostatic. A flat-crested weir of considerable breadth will result in a pressure distribution that

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for all practical purposes increases uniformly from surface to bottom. Although the author has correctly stated that such perfect uniform distribution is actually not attainable, I have observed on a well-designed flat crested weir it is so nearly uniform that such a weir is one of the most accurate measuring devices we have, much more satisfactory in many respects than a sharp crested weir. The water level downstream may be raised to a depth sufficient to cause a true hydraulic jump, in other words, to a depth considerably greater than that on the weir itself before there is any appreciable reduction with the coefficient of weir discharge. This co-efficient is $\frac{2}{3}\sqrt{\frac{2}{3}g} = \text{about } 3.09$.

Although it is true, as the author states, that the head upstream from a control section is what governs the rate of flow, I have found that in most computations of the flow through transitions and other channels the known quantity is the water level at the downstream end of the system, and it is better to commence at this end and carry the computations upstream. The existence of all control sections will then be disclosed with a minimum of time and effort and a fresh start made at each such section continuing always to work upstream.

Very few of us make such computations often enough to warrant the use of diagrams such as the very excellent ones which the author has presented. One who only occasionally wishes to determine a water surface profile needs only a slide rule and a working knowledge of Bernoulli's theorem, and should bear in mind the following:

1. Begin at the downstream end.
2. Refer everything to the total or energy gradient. This and not the water surface must be the primary object of the computation.
3. Bear in mind the possibility of two depths, depending on whether v is greater or less than $\sqrt{gd}$.
4. Bear in mind that it is impossible for the water level to change from the upper to the lower depth or *vice versa* except when these two depths coincide, namely, at a "control section," where $v = \sqrt{gd}$; except that the level may change suddenly from the lower to the upper if the hydraulic jump formula is satisfied, and only if it is satisfied.
5. Also bear in mind that such sudden change or jump must occur downstream from every control section that involves loss of head, since this is the only way in which the energy of the water can be dissipated.

An interesting consideration in connection with the hydraulic jump arises from the fact that all velocity is relative. We are so in the habit of expressing velocities with reference to the earth's surface that it is well to call attention to the fact that velocities in the hydraulic

jump formula are relative to the position of the jump and not relative to the earth's surface unless, as is usually the case, the jump is stationary. For example, it is possible to have a hydraulic jump from still water if the position of the jump itself is moving upstream with a velocity that will satisfy the formula. The bore, a well-known phenomenon in certain tidal rivers, is an illustration of the case in point. It is also possible for a sudden heavy rain on a steep watershed to find conditions which will satisfy the jump relation and cause a standing wave to travel downstream. Similarly, sudden closure of a gate in a flume will cause a wave to travel upstream, whose velocity must satisfy the jump relation.

PROF. C. FRANK ALLEN PRESENTED WITH DIPLOMA OF HONORARY MEMBERSHIP

PROF. C. FRANK ALLEN was elected to Honorary Membership on March 16, 1932. He was presented with the diploma of Honorary Membership at the meeting on April 20, 1932. Prior to the presentation, a biographical sketch of Professor Allen was read by Prof. Charles B. Breed, as follows:

Prof. C. Frank Allen

More than usual there is a personal touch to this occasion, for in this audience I see many fellow engineers who share with me the gratitude that fortune brought them as students into Professor Allen's classes. And there is hardly a man here who has not used his published books to advantage in his professional career.

As most of you know, I was one of those fortunate beings who sat at his knees and there learned my first lessons of curves and earthwork and railway economics. But my opportunities ran much farther, for I not only was one of his many students, but for seventeen years I served as his assistant at Technology, and later had the good fortune, and rather difficult one, of succeeding him as professor of railway engineering in the Massachusetts Institute of Technology. He set a high standard for me. I realized it then; its good influence I hope is with me still. There were times when services as his understudy were a bit disciplinary, but of the healthy sort, for he strove for a very definite ideal and he required and expected a high order of performance. For this early training I am deeply grateful.

Professor Allen's career has been unique, as is that of many successful educators. In his early life prominent educators influenced his thought in a marked degree. He felt keenly that his earliest conception of good teaching came from his contact with the influence of the Roxbury Latin School of which W. C. Collar was principal. Collar was certainly at that time the leading educator of secondary schools in New England, and probably in the United States. Professor Henck of Technology also left his mark on Professor Allen's ideals. Professor

Henck was an excellent mathematician and a thorough teacher, as were also Professor Osborne, professor of mathematics, and Professor Ferdinand Bocher, professor of language. Every college man, because of his temperament, his ideals, or for other reasons, naturally elects certain professors as those who have peculiarly influenced his career. These men I have mentioned are a few who had a decided effect upon Professor Allen's career.

President Rogers of Technology was another man who influenced him profoundly. Professor Allen has quoted to me the words of Rogers given at his address to the entering class in 1868 which so impressed him as to cause him to recall them on several occasions: "You now stand upon the pedestal of the young gentleman — you are schoolboys no longer." This profound lesson Professor Allen never forgot. Its effect was obvious throughout his long career as an educator.

He was a member of the fourth class to graduate from M. I. T. in '72. His first practical experience was under Howard A. Carson, first as a surveyor in the office of J. Herbert Shedd, and later as an engineer on the Providence Water and Sewerage Works — a fortunate start. He left this employment to take charge of the construction of the reservoir on Hammond Street, Boston, which is now a distributing reservoir for the Metropolitan Water System.

About this time there developed the longest period of business depression the country had then known. All college graduates are now facing the problem he then faced. Jobs were not to be had in the East. Professor Allen in 1878 went West to find opportunity on the Atchison, Topeka and Santa Fé Railroad. For the greater part of eight years he was with that railroad principally on office work at the main office of the chief engineer. For a considerable part of that period he was in charge of the office, reporting directly to the chief engineer. For a year, however, he was chief engineer of the water works of Las Vegas, New Mexico, and for a few months with the Mexican Central Railroad at El Paso.

While with the Atchison his work brought him intimately in touch with the legal department in the settlement of right-of-way claims and other litigation. This led him to the study of law, with the result that he later became a member of the bar of New Mexico and local attorney for the railroad at Socorro, New Mexico. At the same time he was city attorney of Socorro.

At his father's death in 1887 he returned East and met Professor Swain, then head of the civil engineering department of M. I. T. Professor Swain asked him to take charge of the instruction in railway

engineering at Technology. This proposition he accepted and held the position until 1916, when he retired after twenty-nine years of signal service.

During this period he published his classic on "Railroad Curves and Earthwork" and its companion volume, "Field and Office Tables."

Upon his retirement and some time after he had been admitted to the Massachusetts bar, he wrote his well-known book on "Business Law for Engineers" which is found on the shelves of many practicing engineers. The success of his law book is doubtless due not only to his knowledge of law but also to his experience in engineering work, and the facility acquired in teaching for presenting his subject effectively, coupled with his logical and concise habit of mind.

In the American Railway Engineering Association he has been active on committee work, and was one of its earliest members. His more important service to that association has been his contribution to the work of the Committee on Uniform Contract Forms.

He has been secretary of his M. I. T. class from the beginning, was secretary of the Alumni Association, and has been a member of the Technology Alumni Council since its formation. The Technology Review was brought into being by a committee of which he was also a member.

Besides the recognition accorded him by the Boston Society of Civil Engineers by electing him as its president, he has also been president of the Massachusetts Highway Association, the New England Railroad Club, and the national Society for the Promotion of Engineering Education. It was also his contribution to the latter association to assist in the preparation of its constitution and by-laws.

He is now the senior member of the Boston Society of Civil Engineers, and he holds the distinction of being the second in seniority in the grade of "Member" in the American Society of Civil Engineers.

So profound was the effect on his life of successful educators that it even influenced his personal life to the extent that he chose his wife from the family of an educator of high attainments. While in New Mexico he made the acquaintance of the daughter of Hiram Hadley, and she later became Mrs. Allen. Mr. Hadley became the first president of New Mexico College of Agriculture and Mechanic Arts. He was recognized in his early days as an educator of unusual abilities, and at his death was probably the best known and most beloved man in New Mexico.

Professor Allen's wide experience in different parts of the country doubtless afforded him a better opportunity to judge character, which

gave him an advantage as a teacher which some others did not have. His outstanding achievements as an author and educator have made his life an influence on many lives. To those of us who have known him most intimately, these achievements are partly masked by the man himself. It is rare that one is so naturally candid, so uninfluenced by personal feelings, so sure to analyze the problem from his own standards of right and fairness. I may be pardoned for recalling just one incident. While I was acting as his assistant at Technology, I recall a special incident as significant or unusual, for as I remember it happened only once. He came into my office one day and said, "Here is a paper written by Mr. — and I prefer that you should rate his paper, for I am prejudiced against this man. I don't like him." To one so familiar as I was with the nature of the man, — with the significant fact that, as it seemed to me, he always bent over backward to be fair in his judgment of men, — this incident seemed most singular as it did unnecessary. His judgment of students was exceptionally accurate, as their later careers often evidenced.

So the occasion of this evening is by no means one that Professor Allen can alone enjoy; for in this audience are scores of men who are happy, indeed, to see the man, who has directly and indirectly favorably influenced their personal and professional careers, honored by the Society with which more than any other he has been closely associated.

RESPONSE BY PROF. C. FRANK ALLEN ON RECEIVING DIPLOMA OF HONORARY MEMBERSHIP

Mr. President and Fellow Members of the Society: I wish to thank the Society for this very kind act. I wish to express my gratitude, also to the Board of Government through which this action must needs be taken, and to my sponsors, whoever they may have been. I wish, also, to express my thanks to Professor Breed for his kindly feeling and the gracious words spoken.

This Society is the first of this sort that I joined. I have always held it in high esteem and have always tried to be loyal to it. This afternoon a gentleman asked me if I was going to the meeting of the Unitarian Club in West Roxbury. Then he said, "Oh, you are not a member, are you?" I said "No; you see your meetings come the same evening as the meetings of the Boston Society of Civil Engineers, and they elected me President at one time, and I have thought it would be disloyal to make another regular engagement for that evening."

My first connection with this Society was in 1875, less than a year after the reorganization of the Society. I was pleased to be elected a member.

Some years later I sat behind Desmond FitzGerald, just then appointed Chairman of the Nominating Committee, and heard him say, "Now it is time to do something for Henry Manley" who at that time had long been treasurer and also regularly chairman of the annual dinner committee, the most beloved man in the Society. There were required three nominees for president. The election was on a competitive basis. After a considerable interval I received a letter from Mr. FitzGerald asking me to accept a nomination for president, to which was added, "Now don't kick." It was a foregone conclusion that Henry Manley would be elected, but I wrote Mr. FitzGerald: "I wish you to understand that I consider it an honor to be 'nominated' for President of the Society." As I have said, I then felt honored.

It came about later that I was thought well enough of by the membership to be elected President. If then I was somewhat elated, certainly now, with this conspicuous honor, I am tonight simply overwhelmed.

Professor Swain, in his presidential address to the Society for the promotion of engineering education, took for his theme the profession of engineering teaching, and I recognize and am glad to believe that in honoring me you are unquestionably honoring quite as much the Profession of Engineering Teaching, as I think you also did at the time Professor Swain was elected President of this Society. Possibly his conspicuous work, more definitely in engineering, made this feature less marked in his later election as Honorary Member.

The list of Honorary Members, which I looked over a short time ago, is a very distinguished one. It seems clear that this Society has been very careful heretofore in selecting its Honorary Members.

To mention two of those Honorary Members, in no way to the disparagement of the others, I would like to speak of Mr. Carson and Professor Swain. My first work in surveying was with Mr. Carson, and my first engineering work was with Mr. Carson, on water works and sewerage. When I brought my bride to Boston Mr. Carson and his wife were the first to call upon us. Of course my connection with Professor Swain was very close and very long.

I confess that I cannot measure what the influence of those two men, their habits of thought, their standards, their character, may have had upon what success I may have attained. I think none of us, especially teachers, can at all appreciate what may be the effect of what

we do for others. The simplest, most inconspicuous thing oftentimes will have a strong after influence upon students. This relates particularly to matters not in the curriculum. I remember one student — a graduate of another college — to whom I told a little story of my experience in the West. He stated to me a few years later that that story was the most important thing he got at Technology. Probably it was not quite true, but it represents an idea, — the influence of little things.

This leads me to call to your attention a very brief poem of which I am rather fond, by an author of whom I am fond, also — Nixon Waterman:

A rose to the living is more
Than sumptuous wreaths to the dead;
In filling love's infinite store,
A rose to the living is more,
If graciously given before
The hungering spirit has fled, —
A rose to the living is more
Than sumptuous wreaths to the dead.

I find myself now basking in the sunshine, inhaling the fragrance, the sweetness of your rose, or, shall I say, the garland, which you have given me while I am still young. I thank you again.

DISCUSSION OF PAPER BY MR. FRANK B. WALKER ON "VISUAL INSPECTION OF METAL ARC WELDS."

ANTHONY S. COOMBS,* MEMBER

THE paper by Mr. Walker † on "Visual Inspection of Metal Arc Welds" is very timely. Arc-welding is coming into a constantly increasing use as a tool in the structural field. The engineer who employs this method must assure himself that the welding for which he is responsible is properly and safely done. Mr. Walker in his paper points out the characteristics of good and bad welds, and a careful examination of the welded specimens at the Society rooms should be of interest to all engineers.

At the present time, visual examination is the most practical method of inspecting welds used in ordinary structural work. Other methods involving more or less apparatus are being developed, and may in the near future come into more extended use. But with intelligent visual inspection the suitability of welds for load carrying capacity may be promptly determined.

Not only should inspection cover the completed welds, but it should begin before the first production weld is made; that is, preliminary tests of all prospective welders should be required, in order to insure that the welders employed have the ability to produce work of the proper quality. These tests may be simply lap welds, to be broken and examined for quality, or for more important work may include specimens for laboratory testing.

An experienced inspector who is on the work while welding is in progress will use his ears as well as his eyes. A short arc properly held gives off a characteristic steady crackling sound, easily recognized. A good workman will maintain this arc for the available length of his electrode, within the limits of the weld. If he has a tendency to let the electrode stick, it is indicated by the interruption of the arc. Too long an arc, also, has its characteristic sound, more of a hiss, inter-

* The Whitney Engineering Company, 100 Arlington Street, Boston, Mass.

† Journal of the Boston Society of Civil Engineers, April, 1932.

rupted with occasional popping sounds as globules of unfused metal are deposited.

The selection of an inspector involves considerable responsibility, and a very desirable qualification for inspection work is actual welding experience. If the inspector is a qualified welder himself, so much the better, but he should at least have had some welding experience. Such an inspector will more readily recognize and detect defects in technique that might tend to impair the quality of the weld.

The writer agrees with Mr. Walker, that good welds will be made with proper procedure, and when completed may be recognized as such by intelligent visual inspection.

DISCUSSION OF THE PAPER ON "STRUCTURE OF CLAY AND ITS IMPORTANCE IN FOUNDATION ENGINEERING"

J. R. WORCESTER*

THE paper of Mr. Casagrande published in the April, 1932, JOURNAL, is of vital interest to all engineers and architects who have to deal with Boston foundations, because by far the larger part of our structures depend upon clay for their support. The more we can learn about this intricate subject, the better we should be fitted to cope with the problems involved, and the paper is brimful of food for thought. Unfortunately, however, it so emphasizes the points about which we are ignorant, that it seems to cut out much of which we felt reasonably sure without substituting enough support to make good the loss.

For instance, we are told that "a definite bearing value for clay does not exist;" that it is not possible to determine from loading tests on clay a knowledge of what settlements will occur; that for the Boston clay . . . the settlements are still too large; that settlements progress though at a decreasing rate. We are informed that with a mat foundation the pressure is not uniformly distributed, but is sometimes a maximum at the center, decreasing to very little at the edges, and sometimes the reverse, being small at the center and very much larger at the edges. It seems that the engineer must determine in advance of design how long it will take the proposed foundation to reach a definite amount of settlement, and yet he is given little advice as to how he is to find this out. He is warned not to rely on piles, as they will increase the settlements. Finally, it is stated that the *only* reliable method of reducing settlements is to excavate enough material to balance the weight of the new building.

Among the surprising statements in the paper is the one that the time-settlement curve shown by Fig. 5c should be raised, as stated at the bottom of page 174, in the ratio of h_2^2/h_1^2 . In these formulas h_1 represents the thickness of a sample tested and h_2 the thickness of the underlying clay. It seems to the writer doubtful whether the settle-

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ment would be increased even in the ratio h_2/h_1 . If the settlement is at all proportional to the pressure, it should not vary as the depth, because the total pressure, which includes the weight of the overlying material, is not increased proportionally by the applied load. Then, as to time, it is not clear why the depth of the clay should increase the length of time of the settlement in proportion to the square of the depth. The resistance to percolation may vary directly as the depth to ground-water level, but why more than this?

Another eye opener is the statement on page 190 that "piles may facilitate the drainage of clay on account of the fact that concrete, as well as wood in the direction of the fibers, offers less resistance to the penetration of water than the clay itself."

The main recommendation of the author, namely, that bearings should be distributed over undisturbed soil, so far as possible, will not generally be disputed; but the harmful effect on soil of driving piles into it has not been so commonly understood or accepted. The gloomy prediction of what may be expected in the way of settlements, as indicated by Fig. 18c, and in other places, is certainly alarming, and seems inconsistent with the results of our experience. In a few locations in the Boston district, settlements amounting to inches have occurred in the course of fifty years, but settlements to be measured in feet are practically unknown. In the greater part of the area supported by clay settlements have been so slight that they have not been observed.

As to the disturbing effect of piles on the clay, the author frankly admits that his conclusions are not based upon experimental evidence, but upon superficial appearances. It may be in order, therefore, to cite other considerations besides those mentioned that do not point in the same direction. The question seems to hinge on whether the effect upon the structure of the clay produced by driving a pile into it is analogous to that of remolding a sample in the laboratory. By driving a pile into a mass of clay the first effect is to increase the internal pressure. This great increase of internal pressure is evidenced by Mr. Mohr's experience. The clay is forced laterally and upward to make room for the pile, but expansion under such conditions is not probable. On the other hand, in remolding a sample in the air, it would appear that the loosening of the original compact formation must involve expansion. Is it not reasonable to suppose that the disturbance caused by driving will take less time for readjustment than would be required if complete remolding took place, for even a limited distance from the surface of the pile? The increase in grip which is noticed after only a few hours' rest points to this same conclusion.

In driving piles in sand or gravel it is well known that the ground becomes more compact as more piles are driven. The consolidation in driving in clay is not so apparent, as the clay can more easily move laterally to make room for the pile. Nevertheless, if the clay is not compressible there must be something of the same effect. If this is so, the reason for the positive rule at the top of page 193, that "under no circumstances should piles be driven through sand into clay," is not apparent. To be sure, if the sand stratum is of sufficient depth to properly distribute the load and to give enough grip on the pile to prevent its further penetration, it is unnecessary to drive through it; but it does not seem certain that going through the sand will increase the settlement. It may be that the increase in the internal pressure in the clay through consolidation may give an additional supporting power to the sand stratum. This has long been the theory of the Boston building department, and, so far as the writer knows, it has produced no unsatisfactory results. The case shown by Fig. 23, it must be admitted, tends to substantiate the author's contention, though it would be more convincing if it were not for the difference in loads, the varying depth of the sand stratum, and the possible lack of uniformity in the quality of the clay.

"Boston clay," so called by the author, is evidently something quite different from what is encountered in most parts of the city, and it might be better, in order to avoid misapprehension, to give it some other name. The relative freedom from trouble that we have enjoyed is partly due to a firmer clay, but it is also true that, more or less unwittingly, our practice has coincided with the author's advice, in that our basements have generally required enough excavation nearly, if not quite, to balance the added weight.

The paper is very opportune, just now, while the Boston building law is in the process of revision, and a free discussion of the subject should be of much assistance to the committee in charge of this branch of the work.

OF GENERAL INTEREST

JOHN R. FREEMAN FUND

The establishment of the John R. Freeman Fund was made possible in 1925 by the gift from John R. Freeman, Past President and Honorary Member of the Society. This gift was made in recognition of the inspiration and encouragement which the donor received from his connection with the Society and in fulfilling his desire to enable the Society to be of still greater service to the young men in their profession.

The income from this fund is to be devoted to the encouragement of young engineers. Some of the uses suggested by Mr. Freeman are the payments of expenses for experiments and compilations to be reported before the Society; the underwriting of meritorious books or publications pertaining to hydraulic science or art; the establishment of an annual prize for a particularly valuable paper relating to hydraulics; or the establishing a traveling scholarship for visiting engineering works, reports of which would be presented to the Society.

Upon the Society rests the obligation and responsibility of administering this fund in such a way as to justify the generosity of the donor. The special committee of the Society for carrying out the provisions of the gift consists of John R. Freeman, Chairman, Charles

M. Allen, Charles T. Main, Howard M. Turner and Robert Spurr Weston.

The committee has appropriated the greater part of income for the fund for the establishment of traveling scholarships, providing for study and work in European hydraulic laboratories. The recipients of the scholarship have been as follows: Kenneth C. Reynolds, for two years beginning July, 1927; Samuel Shulits, for two years beginning July, 1928; Clifford P. Kittredge, for two years beginning July, 1930; and for the coming year, Laurence DeFabritis.

MEMOIRS

Erastus Roland Simpson*

DIED SEPTEMBER 23, 1930

ERASTUS ROLAND SIMPSON was born in Harpswell, Maine, on November 29, 1870. He was the son of Erastus C. and Minerva (Trufant) Simpson, and a descendant of William and Agnes L. Simpson, who settled at Simpson's Point, in Brunswick, Maine, in 1728.

Mr. Simpson entered Brunswick High School in September, 1890. He completed a four-year course in June, 1893, and entered the University of Maine, where he was enrolled in the mechanical

* Memoir prepared from information on file at the headquarters of the American Society of Civil Engineers.

engineering department. In June, 1896, he was graduated from the University with the degree of Bachelor of Mechanical Engineering. In 1903 he submitted his thesis and received the degree of Mechanical Engineer.

Directly following his graduation Mr. Simpson entered the employ of the Hancock Inspirator Company of Boston, Massachusetts, as a draftsman on general machine design. After a period of six months with this company he resigned to become assistant engineer with the Metropolitan Park Commission, in Boston, for which he was engaged in drafting, field work, and as an assistant engineer on construction. About a year thereafter he entered the employ of the Contractors' Plant Company of Boston, as head draftsman on mechanical construction.

Subsequent to a year in the service of this company he went to Georgetown, South Carolina, where he was employed as engineer for the Atlantic Coast Lumber Company on mill construction. His work on this engagement was in designing, laying out and superintending the construction of three mills, two power plants, machine shops, railroad shops and docks.

Mr. Simpson was then employed by the late Freeman C. Coffin, M. Am. Soc. C. E., Consulting Hydraulic Engineer, of Boston, as an assistant engineer in general practice. In March, 1900, he accepted a position as engineer for the Chapman Double Ball Shafting Bearing Company of Boston. In this position his work was similar to that of his previous engagements, being mainly in designing and its resulting duties. On May 9, 1903, he went to Toronto, Ontario, Canada, as general manager of the mechanical department for this same company.

In 1912 Mr. Simpson again engaged

in the private practice of engineering as an industrial engineer, in Boston, with an office at 176 Federal Street, which he retained until his death on September 23, 1930.

Mr. Simpson was a member of the American Society of Civil Engineers, the Revere Lodge of Masons, in Boston, and Beta Theta Pi Fraternity. He was unmarried.

Mr. Simpson was elected a Member of the Boston Society of Civil Engineers on October 16, 1901.

Edward Warren Henck*

DIED OCTOBER 26, 1930

EDWARD WARREN HENCK, the son of J. B. Henck and Mary A. Henck, was born in Philadelphia, Pennsylvania, on February 9, 1846. He attended private and high schools, at Dedham, Massachusetts, and the Boston Latin School. He also attended evening courses at Massachusetts Institute of Technology. He studied engineering in the office of his father, who was for many years professor of civil engineering at Massachusetts Institute of Technology. Mr. Henck was a vigorous and husky boy, and at the age of ten years he worked regularly as chainman on the Harvard Branch of the Fitchburg Railroad during the summer of 1856. After that he worked each vacation as rodman and transitman on railroad work, park work, and on the filling in of Back Bay, Boston, with the exception of two years' sea service as an officer in the Navy during the Civil War.

In 1873 Mr. Henck moved to Florida, where he organized the South Florida Railroad, and later the Florida Midland Railway, acting as president of both roads which now form divisions of the Atlantic coast line.

* Information furnished by Mrs. L. J. Hunt.

Later he acted as a consulting engineer, with an office in New York City, retiring in 1906, subsequent to which he resided in Longwood, Florida.

In 1870 Mr. Henck married Mary A. Brewster of Shelton, Connecticut, who died in 1926.

Mr. Henck was elected a member of the Boston Society of Civil Engineers on February 16, 1927.

Henry Dickinson Woods*

DIED APRIL 2, 1931

HENRY DICKINSON WOODS was born in Paris, France, on October 3, 1852, the son of Henry Woods and Annie L. (Dickinson) Woods. His father was long a member of the old-time firm of C. F. Hovey & Co., representing that house in Europe and making his home in Paris for thirty years. It was his custom to return to the United States at least once every four years in order, as an American citizen, to vote in the national elections. It was in Paris, therefore, that his son, Henry Dickinson Woods, spent his boyhood and received most of his education, with an interval of two years in 1866 and 1867, when he came to this country and attended a boarding school at Newport, Rhode Island. In Paris he attended the College Chaptal, and later, the Ecole Centrale des Arts et Manufactures, from which he was graduated in 1875.

After his graduation Mr. Woods came to the United States and spent his first two years in this country as a draftsman and rodman on the dam division of the Boston, Massachusetts, Water Works. He then returned to Paris and spent a part of the next year in association with Edward Badoit, civil engineer, on plans for the St. Louis Senegal Water Works. He spent the year 1879 working with Mr. H. T.

Bartlett, in Paris, on board-cutting machinery, and, in 1880, he again returned to the United States to accept a position as assistant in the office of the city engineer of Newton, Massachusetts, which position he retained until 1884. During his four years as an assistant engineer, Mr. Woods was engaged in general municipal work, highways, heating and ventilating schoolhouses, and alterations to the City Hall and other municipal buildings. He spent the year 1884 in traveling between France, Belgium and England, in the interest of the Carson Trench Machine Company.

In the latter part of 1884 Mr. Woods engaged in the private practice of surveying and building construction, remaining in this business until the latter part of 1887. At that time he gave up his practice to accept a position in the office of the chief engineer of the Massachusetts State Board of Health, to work on investigations relative to the various water supplies of the State and the question of sewerage purification abroad. After leaving the Massachusetts State Board of Health, he was employed for a year as inspector of masonry foundations for bridge work for the city of Newton and the town of Wellesley, Massachusetts.

In 1889 Mr. Woods again returned to Europe as "Ingénieur Expert" with the United States Commission, Paris Exposition, returning in 1890 to the office of the city engineer of Newton as principal assistant, and in 1893 he was appointed city engineer, in which capacity he remained until January 13, 1900. At that time he retired from the engineering profession and began the work which he so loved among his greenhouses, on the hill close to his home.

In his six years as city engineer, the position he filled so well because of his education and wide experience in the

* Memoir prepared by William P. Morse, M. B. S. C. E.

various lines of engineering, both in the United States and abroad, Mr. Woods accomplished a great deal for the fast-growing city of Newton. The Commonwealth Avenue Boulevard, constructed to a width of 120 feet through the center of the city, was completed during his administration.

Because of many fatal accidents it became necessary to abolish the grade crossings along the main line of the Boston & Albany Railroad, and to widen Washington Street to 75 feet. It was during the years that Mr. Woods was city engineer that this great engineering feat was accomplished, which included the widening of Tremont and Park streets and the reconstruction of many main drains along the line of the railroad. During his administration, Bulloughs Pond, which had formerly been a municipal eyesore, was also changed, and is today a beauty spot, in the center of the city.

In 1899 studies and negotiations were made with the Boston & Albany Railroad Company and plans were drawn for the abolition of the grade crossings on the south side of the city. Before this work was definitely started, however, Mr. Woods retired from his position as city engineer, leaving behind him many treasured friends and lasting monuments of work which he had created during the time of his association with the city of Newton.

He was greatly interested in charities all over the world, and contributed liberally to a large number. During and after the World War he was especially interested in the Phare de France, for the re-education of men blinded in the war, and also in the Preventorium, a charitable health center for children established by the Lafayette Association at Chavagnac, France, to which he gave a refectory building. His generosity was well known, and in

his will he made bequests to many charities which he had supported during his life, among which were: the New England Home for Deaf Mutes; Massachusetts Association for Promoting Interests of Adult Blind; New England Peabody Home for Crippled Children; Industrial School for Crippled and Deformed Children; Infants' Hospital; Bethesda Society; Boston Floating Hospital; Boston Society of Natural History; New England Moral Reform Society; Massachusetts Charitable Eye and Ear Infirmary; Stone Institute and Newton Home for Aged People; and Prentiss Normal and Industrial Institute, Prentiss, Mississippi.

Mr. Woods was a member of the American Society of Civil Engineers, the New England Water Works Association, and the Massachusetts Genealogical Society.

He was married in 1894 to Jennie A. Pond of Brookfield, Massachusetts. He is survived by one daughter, Mrs. Ethel P. Coty, and two grandchildren.

Mr. Woods was elected a Member of the Boston Society of Civil Engineers on April 15, 1885. He served as vice-president in 1896-97.

Edward Willard Howe*

DIED JUNE 27, 1931

EDWARD WILLARD HOWE, the son of William and Catherine (Willard) Howe, was born in Braintree, Massachusetts, on August 27, 1846. He attended the public schools of Braintree and was graduated from Middlebury College, Middlebury, Vermont, in 1869.

In 1874 Mr. Howe was appointed assistant civil engineer for the city of Boston, Massachusetts, which position he held until 1914. While serving in this capacity in the office of the city engineer, he had a large and varied experience.

* Memoir prepared by Edgar S. Dorr and Frank O. Whitney, Members, B. S. C. E.

From 1883 to 1887 Mr. Howe had charge of the engineering work on Franklin Park, Bussey Park, Back Bay Park, Marine Park (Iron Pier and Castle Island bridge) and Wood Island Park. As engineer in charge of park construction and maintenance he continued on this work from 1887 to 1897, in addition to that on Franklin Field, Arborway, Jamaica Park, Leverett Park, Riverway, Dorchester Way (later, part of Columbia Road), Strandway (sea wall and filling), Charlestown Heights, Charlestown Playground, North End Park, Charlesbank (between Cambridge and Leverett streets), Neponset Playground, and others. About 1897 a superintendent of parks was appointed by the Park Commissioners, but Mr. Howe continued to attend to the park engineering until early in 1898, when this work was taken out of the city engineer's office.

In 1898 he was placed in charge of building the Ipswich Street bridge, in Boston, over the Fens Waterway, the Charlesgate West bridge, over Ipswich Street, and the Columbia Road filling, in South Boston. About 1899, and later, he constructed the Columbia Road bridge over the tracks of the New York, New Haven & Hartford Railroad, and over Shoreham Street, and was in charge of work in connection with the abolition of the Dorchester Avenue grade crossing, including the bridges and streets at Dorchester Avenue, and Boston and Southampton streets.

About 1901 Mr. Howe had charge of building the Broadway bridge over Fort Point Channel, as well as the Atlantic Avenue bridge over the railroad tracks near the South Station, Boston, and over Fort Point Channel. About 1905 he constructed the temporary bridge at Brookline Street (Cambridge), over the Charles River, and was in charge of work on the abolition of grade

crossings, in East Boston, on the Boston & Albany Railroad. In 1907 the building of the boundary wall and the sea wall on Deer Island was entrusted to him.

From 1907 to 1914 Mr. Howe was engaged upon the sewerage system and surface drainage and road building for the Consumptives' Hospital, at Mattapan, Massachusetts; in 1909 he made many plans and estimates of schemes for the abolition of grade crossings on the New York, New Haven & Hartford Railroad, in the Harrison Square District of Boston; and in 1910 he had charge of the addition to the Dorchester Avenue bridge over the Shawmut Branch of the New York, New Haven & Hartford Railroad, at Ashmont, Massachusetts.

In 1911, when the public works department of the city of Boston was organized, Mr. Howe was appointed engineer of grade crossings and special work. From 1911 to 1914 he was engaged on the abolition of grade crossings on the Boston, Revere Beach & Lynn Railroad, in East Boston; and in 1912 he designed and had charge of the construction of the Lawnsdale Terrace Subway under the Providence Division of the New York, New Haven & Hartford Railroad.

In 1913 and 1914 he made surveys, plans and specifications for rebuilding the Winthrop bridge, between East Boston and Winthrop, Massachusetts. His work included, also, many smaller jobs called for by the various departments, which were done by the engineering department under his direction, until his retirement from active work about 1916.

In 1900 Mr. Howe became president of the Merchants' Co-operative Bank of Boston (director from 1884 to 1900, and president from 1900 to 1918). He joined the Appalachian Mountain Club in 1895, and was vice-president in 1901

and president in 1902. Also he was a member of the American Society of Civil Engineers.

For more than fifty years he was a member of the Sons of the American Revolution, maintaining an active interest in the Boston Chapter. He was also a member of the New England Genealogical Society for many years. In religion, he was a member of the Unitarian denomination, and was especially interested in All Souls Church of Roxbury, Massachusetts.

Mr. Howe was throughout and invariably a mild, calm and courteous gentleman under any and all circumstances.

On April 29, 1880, he was married to Addie E. Newell. He is survived by his widow and three nephews.

Mr. Howe was elected a member of the Boston Society of Civil Engineers on June 8, 1874, and was one of those who took active part in the revival of the Society in that year. He served as Treasurer from 1892 to 1905, and was President in 1907.

George Fillmore Swain*

DIED JULY 1, 1931

GEORGE FILLMORE SWAIN was born March 2, 1857, in San Francisco, and died July 1, 1931, at his summer home in New Hampshire. His ancestors came from New England; the earliest of whom we have record was Richard Swain, who came to America in 1635 and settled first in Hampton. A few years later he moved to Nantucket and was one of nine who, in 1659, purchased the English rights to the entire island from Thomas Mayhew, who, however, retained a twentieth interest. The Indian rights were also promptly acquired. The Swains have been among the best known families of

Nantucket, as have also the Bunkers, who apparently were among his ancestors. Nantucket in its prime was the leader in the whale fishery, and this not only bred sturdiness of character but also brought prosperity with its many advantages. Professor Swain's father was Robert Bunker Swain, and he became one of the leading merchants of San Francisco. He served as president of the Chamber of Commerce there, and was appointed superintendent of the Branch Mint during Lincoln's administration. His work at the Mint brought in play an unusual quality of mathematical ability. The son's success in this direction had some root both in inheritance and example.

Young Swain prepared for college at a military school, and the discipline which goes with such a school may well have had an important influence in forming habits of mind and action which were elements in his later success. He entered the Massachusetts Institute of Technology at the early age of sixteen, and yet led his class in scholarship. He served as adjutant of the military battalion there, — an early index of leadership.

The thorough training characteristic of that institution in its turn could not do otherwise than serve to further develop the habits of thoroughness and of character already fairly established. Among the studies pursued there the non-professional course in logic, taught at that time by Prof. George H. Howison, inspired in young Swain a taste for study along that line, and the reading done in this direction he has valued highly as an important part of his training. He also acquired a fondness for Shakespeare, and this, in connection with his logic, certainly helped not only to clear thought, but habits of clear expression which a training in mathe-

* Memoir prepared by C. Frank Allen, Past-President, B. S. C. E., and published in Journal of the Engineering Societies of Boston, October, 1931.

matics and science sometimes fails to secure.

His teacher in civil engineering was Prof. John B. Henck, a fine mathematician, a strict and clear teacher, who demanded and received good work from his pupils and did more than any other member of the early faculty of "Tech" to fix the high standards of this institution. His influence on Professor Swain's later teaching must have been very great.

In 1877 Swain received his degree of Bachelor of Science in the course of civil and topographical engineering. Not satisfied with this, he spent three years abroad, primarily for the study of civil engineering, in which he did fine work, but with the added advantage to him of acquiring a breadth of view and experience in life, a wide acquaintance with men of various training, and an opportunity to travel, which together formed probably the most valuable feature of his life abroad. This is something which cannot be acquired from travel alone.

He studied at the Royal Polytechnicum at Berlin, under such able masters as Winkler, Goersing and Hagen, specializing in bridges and structures, railroads and hydraulica, — subjects valuable quite as much for training as for knowledge of the work covered. Advanced degrees there were then restricted to those who were to enter government service, so that he received no degrees, but the substance he secured.

With superior natural and demonstrated ability, combined with an excellent foundation secured at Technology, he was in position to benefit, well-nigh to the limit, from the opportunities offered at the Royal Polytechnicum. As an outcome he reached this country probably more highly trained in civil engineering than any of his contemporaries.

On his return in 1880 he was employed

as a special agent of the census in investigating water power in connection with manufacturing interests, his field being the Atlantic slope. He also spent some time in hydraulic work in the office of locks and canals at Lowell, and of the Essex Company at Lawrence.

His water power work was done under Gen. Francis A. Walker, superintendent of the census, who shortly afterward became president of the Massachusetts Institute of Technology. He promptly recognized Swain's ability by appointing him instructor in civil engineering. Early promotion followed to the position of assistant professor in 1883, and a few years later, in 1887, he became full professor in charge of the department of civil engineering. Later the course in sanitary engineering, newly introduced, also came under his direction.

Early in 1887 there occurred the Bussey bridge disaster, and this furnished the first opportunity for Professor Swain to distinguish himself in the engineering field. At the investigation which followed, the quality of his training and his ability to analyze the causes of the accident so impressed the Railroad Commission that he was appointed the first expert engineer of the Commission under a law newly passed, an office which he continuously and satisfactorily filled for many years; an office for which he was well fitted and which yielded him a rare experience. The necessary changes and reforms in railroad bridge practice in the State were secured quietly and effectively and with avoidance of ostentatious publicity.

The prestige of this appointment has been believed by many of his friends to have been a decisive element in his appointment as head of the department at the age of thirty (an early age for conservative Boston). However, his success more than justified his appointment. A remarkable development followed.

At the time when he became acting head of the department, in 1887, he was the only full professor; there were three instructors and one assistant. In 1909 there were in the department twenty, all told; ten of these were members of the faculty. In 1887 there was no department library worthy of the name; in 1909 it had become probably the best working library of civil engineering in the country, and it was due to his enthusiasm and judgment that this was accomplished.

While at Technology he served for a time as secretary of the Society of Arts, connected with it, and was also for two years secretary of the Technology Alumni Association.

In 1909 Professor Swain was offered and accepted the Gordon McKay Professorship of Civil Engineering in the Graduate School of Applied Science, Harvard University. An important consideration in his acceptance was his expressed belief that this graduate school marked an advance in the status of engineering, putting it on the same basis as law and medicine, the schools of which for some time had been on a graduate basis at Harvard. The school was later continued as an undergraduate, rather than purely graduate, school.

As a teacher, his standards have been high. He has demanded from his students not only diligence and attention, but beyond that has insisted upon clear thinking on their part. His work has been very thorough, of a high grade and enforced by a steady drill in the principles of the subject. Here acquirement or an understanding of the subject in hand has been secondary to clear thinking along the line of work. He was a drill master par excellence in a subject which especially lent itself to such treatment.

He taught many subjects at the Institute in the early days, the impor-

tant course in hydraulics being for several years in his direct charge. Later he confined his attention almost exclusively to structures, which he taught not only to undergraduate students but also to graduates. Fate, in part through the Railroad Commission, seems to have decreed that both his teaching and his engineering activity should be largely in the field of structural work.

In 1893 men engaged in teaching engineering in the United States and Canada organized the Society for the Promotion of Engineering Education. Professor Swain was an early President of this society, in which he took for many years an active part. His attitude toward the work of teaching was well defined in his presidential address on "The Profession of Engineering Teaching," in which he called attention to the necessity that professors of engineering should cultivate the teaching side, however attractive the engineering side may be.

This attitude towards teaching shared by his colleagues in the department meant much to the success of his administration. His reputation among the teachers of the country placed him in the front rank. This is attested by the fact that the Society for the Promotion of Engineering Education in 1928 made him its choice as the first recipient of the Lamme Medal, awarded yearly for "accomplishment in technical teaching or actual advancement in the art of technical training." This medal Professor Swain valued most highly.

As an engineer and as an official in connection with engineering work he has had a large and successful experience. Aside from his duties with the Railroad Commission he has been consulting or designing engineer for a number of bridges, movable as well as fixed, an unusual case being the reconstruction of the old chain suspension

bridge at Newburyport as a stiffened cable suspension bridge with a hinge at the center and with reinforced concrete towers.

In connection with architectural construction he was employed upon the large extension of the State House at Boston and upon many other works, some of which offered unusual problems. His activities, however, were not altogether confined to structural work.

In 1894 the Boston Transit Commission was organized to construct the Boston subways. Professor Swain was one of the first commissioners appointed. He served on it for twenty-four years and was its chairman for five years. The work was without precedent in this country, was well carried out and within the original estimates. The tunnel under Boston Harbor to East Boston was a part of the work of this Commission, as was also the Charlestown bridge. The expenditure under this Commission during his years of service, was in excess of \$20,000,000.

He served upon a number of commissions to fix the method of eliminating grade crossings of highways with steam railroads, those at Worcester, Taunton, Newton and Waltham being among the most important. He was a member of the commission to revise the building laws of Boston. He has also frequently been called upon as an expert in court cases, not only in Massachusetts, but elsewhere.

Professor Swain served as expert for the commission on valuation of the assets and liabilities of the New York, New Haven & Hartford Railroad. This involved appraisals of properties and securities held by the railroads, a physical valuation, a consideration of economic problems, and a critical examination of books. This was followed by similar valuations of other roads, both large and small; among them the New York Central and certain Canadian

railways, as well as the Chicago elevated railways. Altogether these valuations ran up to many hundreds of millions of dollars.

In 1908 he was appointed by President Roosevelt a member of the Inland Waterways Commission and also of the Conservation Commission. This followed the hearings of a congressional committee upon the proposed Appalachian Forest Reserve, at which Professor Swain took an important part.

In 1918 he was one of the representatives of the American Society of Civil Engineers, as part of a delegation of nine from the four national engineering societies of the United States, to confer with French engineers regarding the adoption of a program for the rehabilitation of France. He served as secretary of the delegation as well as chairman of two of the subcommittees during a stay in France of about one month. He was also a member of the Franco-American Engineering Commission organized in 1919.

He has been for a number of years one of the board of judges to select names for the Hall of Fame of New York University, and this university, in 1906, conferred upon him the honorary degree of LL.D.

This was followed in 1918 again by the degree of LL.D. from the University of California. He felt especially gratified at receiving this from the State university of his native State.

There were early publications for the use of his classes on "Hydraulics," which were highly regarded; also notes on "Structures;" but these were not given general circulation. The "Journal of the Franklin Institute" for 1883 contains articles from him on "Mohr's Graphical Theory of Earth Pressures" and on the "Applications of Virtual Velocities to the Determination of the Deflection and Stresses of Frames;" in 1887 he contributed a paper to the

American Society of Civil Engineers on the "Calculation of Stresses in Bridges for Concentrated Loads," a feature of which was the use of "Influence Lines." The two last-mentioned papers have had a very material effect upon present practice in structural computations and investigations. He has been active in contributing to various society papers, and many official reports have been made by him, sometimes individually, sometimes as one of a board.

Late in life he started upon a comprehensive treatise in four volumes dealing with structures and materials. The first volume on "Strength of Materials" was published in 1924, as was also the second volume, "Fundamental Properties of Materials." The third volume, "Stresses, Graphical Statics and Masonry," was published in 1927. His sudden illness prevented the completion of the fourth volume. As might be expected, these books were of monumental character, of great value to the profession. His book on "How to Study," 1917, has had a wide and continuing circulation, being required as a part of the engineering courses in a number of colleges. A somewhat later book, "The Young Man and Civil Engineering," was one of a series of touching various occupations or professions, and was well received.

Professor Swain had been a member of many engineering or allied societies, including:

Boston Society of Civil Engineers, of which he has been president and honorary member; New England Waterworks Association; American Society of Civil Engineers, of which he had been president and honorary member; American Society of Mechanical Engineers; American Institute of Consulting Engineers; American Society for Testing Materials; Canadian Institute of Engineers; Institution of Civil Engineers of Great Britain; Society of

Engineers of Hanover, Germany; American Railway Engineering Association; New England Railroad Club; National Academy of Arts and Sciences; American Association for the Advancement of Science, of which he had been a vice-president; American Academy of Arts and Sciences; American Forestry Association; Society for the Promotion of Engineering Education, of which he was senior past-president.

To a civil engineer the highest honor to which he may aspire is the presidency of the American Society of Civil Engineers, and to this post Professor Swain was elected in 1913, the first professor of engineering to be so honored, and this qualification was doubtless a factor in his selection, although this was justified either by his standing as engineer or because of faithful and efficient work within the Society.

He had long been of the opinion that activity in the Society should precede rather than follow election. By this standard he qualified well. He had contributed papers to the Society, had served on important committees, had been a director and a vice-president of the Society, and was held to be an influential member of the board of government. Additional distinctions came from his elevation to honorary membership in 1929.

He has long been a pronounced believer in the advantage to engineers of associating more largely with business and professional men not engineers. His presidential address to the Boston Society of Civil Engineers dealt with this subject; and consistently he had been a member in Boston of the Union Club, a general social organization, the St. Botolph Club, where literary or similar qualification is necessary, the Commercial Club, whose name indicates its business character, and the Boston City Club, very cosmopolitan in character. He was also a member of

the Harvard Club and the University Club.

Neither was he averse to recreation. He enjoyed both whist and billiards, at both of which he played a good game. He was also fond of music and played the piano with skill and taste. It was his habit to do things well.

Professor Swain had a fine library, not only of scientific and professional books, but also along varied lines, including economics as well as general literature which appealed to him. His library contains many books in German and French, and he read freely in both languages, both as literature and as scientific treatises.

He was thrice married, to Katherine Kendrick Wheeler, to Mary Hayden Lord and to Mary Augusta Rand, who survives him, as do also a daughter Barbara, an assistant professor at Vassar College; a daughter Clara, also a graduate of Vassar; a step-daughter, Alice Rand, now married and resident in Chicago.

Professor Swain's success may be attributed in part to inherited ability and fine environment at home and at school, both here and abroad, a training

extended beyond that secured by most of his fellows; an orderly habit in his work and economy of effort, avoiding waste; a faculty for clear thought and clear expression; a remarkable capacity for hard, rapid and concentrated work, together with an appreciation of short cuts and effective methods.

He possessed the valuable faculty of taking advantage of his opportunities, the lack of which has spelled failure to many otherwise able men.

It is not easy to record the sense of personal loss felt by his many friends who held him in high esteem. Many who visited him in his last sickness will rejoice that the honors so much appreciated by him, the Lamme Award and the Honorary Membership, happily came to him as a meed of cheer as the sun was slowly setting upon an active, well spent and useful life.

He was elected a Member of the Boston Society of Civil Engineers on January 18, 1882, was President in 1896, and elected an Honorary Member on September 19, 1917.

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS

Boston Society of Civil Engineers

MAY 18, 1932. — A regular meeting of the Boston Society of Civil Engineers was held this evening in Chipman Hall, Tremont Temple, and was called to order at 7.10 P.M. by the President, Ralph W. Horne. About 90 members and guests were present. The usual buffet supper preceding the meeting was attended by 58 persons. This was a joint meeting

with the Highway Section of the Boston Society of Civil Engineers.

The minutes of the Annual Meeting on March 18, 1932, were approved as printed in the April JOURNAL.

Announcement was made of the death of George A. King, who died on April 26, 1932, and had been a member since December 19, 1888.

The Secretary reported that the following new members had been elected by the Board of Government on May 18, 1932:

Grade of Member: Arthur Casagrande,

Thomas G. Giblin,* George Nelson Perry,* John Grimes Walker Thomas.

Grade of Junior: Morris Bernard Burstein, Stewart Henry Presper.

The Secretary reported the results of the letter ballots on the adoption of amendments to the constitution to provide for the Grade of Student Members, as follows: total number of ballots cast, 268, — "yes," 262; "no," 2; blanks, 4. The President then declared that the amendments, which were first voted upon at the last meeting, April 20, 1932, and now voted upon by letter ballot, has been adopted so as to read as follows:

Article 11. Membership

(First Paragraph)

The Society shall consist of Members, Honorary Members, Juniors, Students and Associates.

(Fourth Paragraph)

Juniors shall be not less than eighteen years nor more than twenty-five years of age, and their connection with the Society shall cease when they become twenty-six years of age, unless they be previously transferred to another grade. They shall be in active practice in some branch of engineering, or other technical profession, or graduates from a school of engineering of recognized standing. *Students shall be students in a school of engineering of recognized standing. Their membership shall cease at the annual meeting following the severance of their connection as students, unless they shall have transferred to another grade of membership.*

The President stated that at the last meeting of the Society, April 20, 1932, the Society voted to adopt proposed amendments to the By-Laws which would —

1. Fix the date of the September meeting as the fourth Wednesday of the month.
2. Provide for the election of Student Members and fix the dues for the same.

The proposed amendments to the By-Laws are as follows, and are indicated in italics:

AMENDMENTS TO BY-LAWS

Article 1. Meetings

Regular meetings of the Society shall be held on the fourth Wednesday in January and September and on the third Wednesday of the other months, excepting July and August, unless otherwise authorized by the Board of Government.

Article 7. Election of Members

(Add new paragraph at end of Article 7)

An applicant for Student Membership shall submit a statement that he is a bona fide student in the Institution which he is attending. This statement shall be signed by the Dean, Registrar or other officer of the Institution acceptable to the Board of Government.

Article 8. Fees and Dues

(First Paragraph)

The entrance fee for Members and Associates shall be ten dollars, and for Juniors, five dollars; a Junior transferred to the grade of Member or Associate shall pay an additional fee of five dollars. *There shall be no entrance fee for Students. Students who transfer to another grade shall pay the entrance fee for that grade when the transfer is made.*

(Second Paragraph, First Sentence)

The annual dues, payable in advance at the Annual Meeting, shall be as follows: by Resident Members and Associates, ten dollars; by Non-Resident Members and Associates, six dollars; by Resident Juniors, five dollars; by Non-Resident Juniors, four dollars; and by Students, *three dollars, for a full year or fraction thereof.*

Voted, That the proposed amendments to the By-Laws be adopted. This is the second and final action in this matter, inasmuch as the Society has by letter ballot just adopted amendments to the constitution to establish a grade of Student Members.

The President stated that the Board of Government authorized the circularization of a petition for voluntary signatures urging the congressional representatives to take action tending to balance the Federal budget.

* Transfer from Grade of Junior.

Announcement was made that the Society will hold a joint outing with the New England Water Works Association in June, to take the place of the regular Society meeting.

The President then introduced Mr. J. L. Herber, Engineer, "Incor" Division of the Lone Star Cement Company of New York, Inc., who gave a very interesting talk on "Recent Developments in Concrete Construction." This was followed by lantern slide illustrations. The speaker described the development and behavior of "high-early-strength" Portland cement; progress made in avoiding non-productive periods in construction schedules; complete economic data on savings made possible in construction of tunnels, sewers, highways, bridges, concrete piling and reinforced concrete buildings.

Motion pictures of construction of George Westinghouse Bridge at East Pittsburgh, Pennsylvania, a five-span, high-level reinforced concrete arch structure spanning Turtle Creek Valley, and containing the longest span of its kind in the Western Hemisphere.

The meeting adjourned at 9.30 P.M.

EVERETT N. HUTCHINS, *Secretary*.

Designers Section

MAY 11, 1932. — The regular meeting of the Designers Section was called to order at 6.10 P.M. by the Chairman, Lawrence G. Ropes, in the Affiliation Rooms.

The minutes of the April meeting were approved as read.

The Chairman introduced the speaker, Prof. Edwin H. Wright, Head of the Fine Arts Department, Tufts College. Professor Wright took as his subject "Beauty in Bridges." He showed many lantern slides of bridges constructed at various periods from the time of the Romans up to the present day and located in many different countries. His remarks were most interesting, as he discussed the beauty, or absence of beauty, in the design, and pointed out features that would have improved the appearance.

A general discussion followed the talk,

after which the meeting adjourned at 7.45 P.M., with a rising vote of thanks to Professor Wright.

Forty members and guests were present.

HERMAN G. DRESSER, *Clerk*.

APPLICATIONS FOR MEMBERSHIP

[June 20, 1932]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of fifteen (15) days from the date given.

For Admission

JULIAN, OLIVER G., Boston, Mass. (Age 42, b. Jersey City, N. J.) Graduated as civil engineer from Pennsylvania Military College in 1909. Special student at Columbia University in 1910. Experience as rodman, transitman, inspector, draftsman, etc., from 1910-14; steel inspector, Brooklyn-Manhattan Railway, 1914; engineer with B. J. & J. J. Mack, general contractors, 1916-18; U. S. Army, 1918; Treasurer of O. G. Julian Engineering and Construction Company, Jersey City, N. J., 1919-25; assistant engineer, chief inspector and engineer, with Gibbs & Hill, consulting engineers, New York City,

1925-29; engineer with Jackson & Moreland, June 1, 1929, to date. Refers to *W. W. Bigelow, E. H. Cameron, J. C. Damon, R. A. Freeman, E. L. Moreland.*

MYOTT, E. B., Reading, Mass. (Age 35, b. Barton, Vt.) From May, 1913, to March, 1916, rodman and transitman with Chandler & Palmer, civil engineers, Norwich, Conn.; March, 1916, to January, 1917, transitman and chief of party with Boston & Maine Railroad on bridge and track surveys; February 18, 1917, to July 25, 1917, chief of party and assistant to construction superintendent, New York State Dredging Corporation; August 13, 1917, to April 20, 1918, chief of party and draftsman, with Aspinwall & Lincoln on city surveys, lines and grades; April 20, 1918, to August 1, 1918, draftsman with Fay, Spofford & Thorndike, on general field office work at Boston Army Base; December, 1918, to date, draftsman, designer and resident engineer on investigations, reports, designs and construction of various municipal projects with Fay, Spofford & Thorndike. Refers to *C. A. Farwell, R. W. Horne, F. H. Kingsbury, O. E. Parks, A. D. Weston.*

ADDITIONS

Members

ARTHUR CASAGRANDE, Massachusetts Institute of Technology, Cambridge, Mass.

WILLIAM L. HYLAND, 14 Charles Street, Norwood, Mass.

JOHN G. W. THOMAS, 88 Bay State Road, Boston, Mass.

Juniors

ADOLF W. KREUSEL, 11 Dunboy Street, Brighton, Mass.

CARL L. MORK, 153 Naples Road, Brookline, Mass.

EDWARD F. WILCOX, 247 Kent Street, Brookline, Mass.

DEATHS

CHARLES L. EDGAR . . . April 14, 1932

GEORGE A. KING . . . April 26, 1932

FRED E. HESS . . . May 1, 1932

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FOUNDED 1848

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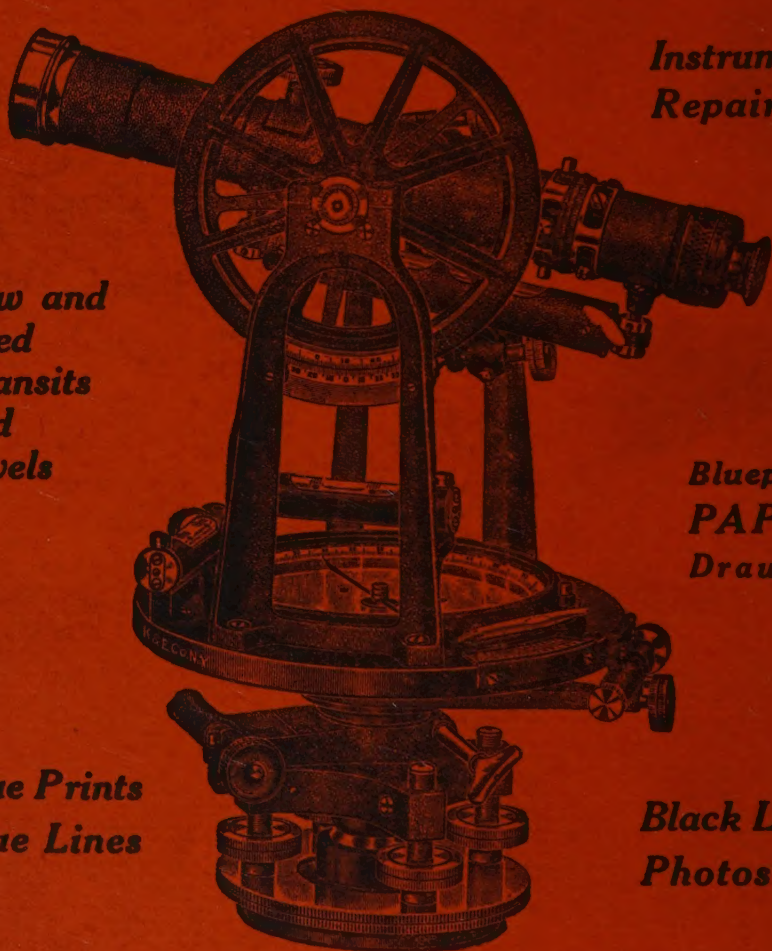
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